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PRESSURE FIELD DATA ACQUISITION ON A PHYSICAL WELL MODEL USING A MINICOMPUTER

BY

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PURPOSE OF THE WELL MODEL

A physical well model is being used to determine the efficiency of various well screens and well screen development techniques at the Bureau of Reclamation Hydraulic Laboratory in Denver, Colorado. Head losses due to the effects of size, orientation, and configuration of the openings in different types of well screens can be lessened through various well development techniques. This reduction of head loss is beneficial because, when the head loss is reduced for a particular well, the pumping cost associated with that well can also be reduced.

REASONS FOR A COMPUTER DATA ACQUISITION SCHEME

The physical well model data acquisition system must gather pressure field and flow through the pump data at specified timing intervals.

Since the physical well model is a porous media problem, a large amount of pressure data is required for adequate understanding of each situation being tested. In particular, five levels of nine piezometers each, placed in a radial line to the aquifer boundary, were determined to be necessary in the analysis of each well screen (figure 1). Seven more piezometers are required to locate the piezometric surface.

A magnetic flowmeter for measuring the pump outflow was determined to be the best choice for measuring the aquifer flow. This choice was made on the basis of the accuracy available with the magnetic flowmeter and the ease of making measurements with the device.

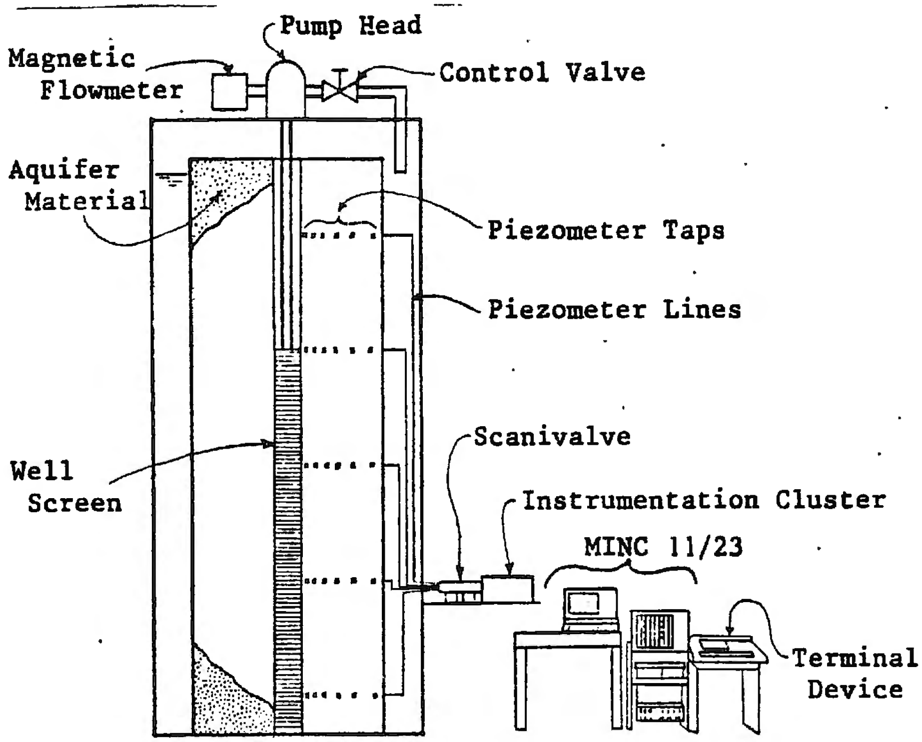

Figure 1. - General section view of the physical well model and minicomputer data acquisition system.

Thus, for the well model, the basic data acquisition requirements are for 52 piezometers to be read along with concurrent flow rates at predetermined time intervals. To maintain accuracy, the pressure, which is read in terms of head, needs to be read to one millimeter. Without the aid of a computer data acquisition system, attempts to gather the above data could have been very difficult. However, through the allocation of one additional piezometer for calibration purposes, a computer can be programmed to gather and process data with a minimum of researcher interaction.

COMPUTER SYSTEM FIRST SELECTED

At the time the physical well model study was first instituted (1976), the computer system available to the Hydraulic Laboratory was referred to as the Measurement, Analysis and Control (MAC) computer system. The MAC computer system was not in any form a minicomputer; however, through utilization of "stand-alone" units, it served many users. Therefore, the MAC computer system could be and was utilized, via a "stand-alone" unit, to perform the data acquisition on the physical well model. Programs were created on the MAC computer system, compiled and then stored on the system's disk. The "stand-alone" unit could then be used to request MAC to download the needed program, and operate the unit's peripherals to gather data from the physical well model's instrumentation on the basis of the downloaded program's instructions; further, using the downloaded program's instructions, it could request the MAC to accept an upload of the resulting test data to a magnetic tape drive resident on the MAC. Another program which was created on MAC could then be used at the MAC site to create a hard copy of the data in formatted form and an ASCII (American Standard Code for Information Interchange) paper punch tape. The ASCII paper punched tape was used to load the data on a much larger computer system capable of performing a full, detailed analysis of the data and outputting high quality graphic results. (A Cyber 730 computer is currently used by the Bureau of Reclamation as its larger computer system.)

The MAC computer system was satisfactorily operating the well model data acquisition system until, in 1980, the MAC computer system began to develop serious problems. However, the Hydraulic Laboratory and, in particular, the personnel responsible for operation of the physical well model continued to use their existing "stand-alone" unit in conjunction with the MAC computer system. In 1981, a major hardware problem with MAC necessitated an economic decision to surplus the MAC computer system and develop a new computer system utilizing a minicomputer. In addition to the well model study, the new system would be used on other physical model studies.

SELECTION OF A NEW COMPUTER SYSTEM

Two major considerations, hardware and software, were taken into account when the minicomputer was being selected.

Hardware considerations

Hardware considerations basically consisted of the following:

1) The Hydraulic Laboratory is enclosed in an area of approximately 4900 square meters (1.21 acres). To avoid the necessity of stringing a multitude of hardlines, the system must be extremely portable. A single transportable cart is preferable so the minicomputer can be easily moved as needed to many different locations in the Laboratory.

2) The hardware must be capable of withstanding the dust and humidity prevalent in a hydraulic laboratory environment.

3) Since field studies are sometimes required to supplement laboratory studies, the hardware must be capable of being transported, without serious difficulty, to a field setting.

4) For each particular physical model study to use the minicomputer system without serious disruptions, the system must be highly flexible. This requires the laboratory data acquisition cards to be removable thereby allowing other laboratory cards to be placed within the computer system.

5) Hookups and disconnects, to and from instrumentation, should be relatively easy and simple for personnel to perform.

6) Memory core available should exceed 32K with 64K being a preferable memory size.

7) As well as being reliable and easily accessed, the permanent storage media should be relatively large and durable.

Software considerations

Software considerations basically consisted of the following:

1) Software life should be long, preferably exceeding the life of the ongoing research project.

2) Software must be capable of use both by the programmer, who deals with more complex system requirements, and the nonprogrammer.

3) In addition to the system's own assembly language, the software must be able to offer users both Basic and Fortran languages. These high level languages must offer a fairly extended capacity.

4) The computer system must have a large high level language library, and this library must be capable of expansion by the users for their own special needs.

Additional considerations

Additional considerations, specifically relating to the physical well model, used in the selection process were:

1) The physical well model tests, which are to be performed through use of the minicomputer, have to be compatible with the large number of tests previously performed through the outdated MAC computer system.

2) The minicomputer system has to be capable of reliably transferring data, at a high rate of speed, to the Cyber computer system.

3) Previously developed, existing programs for the physical well model, used in analysis and graphic output residing on the Cyber system, should be able to use MAC created data and minicomputer data without modification.

Final decision

Based upon supplier demonstrations, past experience and the requirements for the Hydraulic Laboratory, a Modular Instrument Computer (MINC 11/23) was selected and delivered by its manufacturer.

CREATING AN OPERATIONAL SYSTEM FOR THE PHYSICAL WELL MODEL

Creating a new system, which would be operational on the physical well model, required a new design analysis of the model's existing instrumentation. The operation technique, while compatible to the old system's output, had to also conform to the MINC system and be able to fully utilize it.

Instrumentation needs and problems overcome

Major problems for the physical well model's minicomputer data acquisition system were primarily instrumentation related.

Transducer impulse response A transducer converts pressure to a voltage signal. The worst contingency for the transducer utilized in this study is a square input wave. For this square input wave a typical characteristic response curve can be created and will define the minimum timing interval for accepting a pressure change at five-tenths (0.5) second. This minimum timing is close to some transducer input interference; however, by taking a large data sample over a one-tenth (0.1) second range and reducing the data to a single point, any error(s) introduced by the occurrence of the worst contingency case are damped out.

Scanivalve response Each piezometer tube could be directly linked to a transducer. However, considering the requirements of the well model study, this would be both expensive and inefficient. A scanivalve is a piezometer position control device. With the scanivalve, only one piezometer is allowed to be read at any one time. Therefore, placement of a scanivalve before a transducer reduces the required number of transducers to one. An electrical controller and digital readout allow for either manual or computer controlled operation of the scanivalve; during tests, the computer takes complete control of the scanivalve.

The scanivalve being used in the well model study has a response of 30 milliseconds for forward stepping and a spring return or spring rebound time requirement of 15 milliseconds, for a total time lapse requirement for a full cycle, from step impulse, of 45 milliseconds. The MINC system software was found to require 10 milliseconds to operate the scanivalve; therefore, the scanivalve's time requirements supersede the program's requirements, and the program must wait for the scanivalve cycle to be completed before continuing to the next program step.

Electromagnetic interference The portion of the Hydraulic Laboratory which houses the physical well model has some minor periodic interference on the flowmeter voltage output. The source causing this interference has not been identified but is believed to be related to fluorescent lighting located close to the magnetic flowmeter. It has been determined that the technique utilized to overcome the transducer response problem will also dampen this interference, thereby making it negligible.

Timing speed For each piezometer reading, the time lapse from the point of the first piezometer reading is necessary. This elapsed time is used in the analysis and graphic output. Since a multiple number of reads per piezometer is required for interference damping, a clock-driven analog-to-digital sweep was determined to be the best way to accomplish the multiple reads. Therefore, manufacturer generated clock software for both the in-line and laboratory clock card are required.

Instrumentation updated To avoid potential problems, it was decided to moderately update the well model's instrumentation during the MINC system program development phase. This update included installation of several new power sources to enable the MINC system to control the scanivalve and power a differential amplifier (used to boost the transducer signal). Also, a reduction in the magnetic flowmeter's maximum voltage output was required. (The MINC analog-to-digital card has a maximum input capacity of ±5.2 volts due to an internal voltage reference source.)

Instrumentation recap Therefore, the final instrumentation required for the well model minicomputer hookup was: scanivalve with a step-home controller and digital readout of piezometer position, differential amplifier, magnetic flowmeter, transducer, and necessary power sources to power each device. Finally, the wires were attached to prefabricated clips and plugs, which can be easily attached to the MINC system.

MINC laboratory cards required In addition to the basic MINC 11/23 equipment, the well model required some laboratory cards.

1) Analog-to-digital (A/D) card. The A/D card is used to receive voltage data from the transducer and magnetic flowmeter.

2) Digital-in (DI) card. The DI card is used to verify the piezometer position on the scanivalve.

3) Digital-out (DO) card. In this instance, the DO card is used as a relay to give step and home impulse commands to the scanivalve controller.

4) Clock (CKW) card. The CKW card is used to obtain data from the A/D card in a tightly packed form within a specified time span.

PROGRAMMING THE MINC SYSTEM

Program types

Two basic types of tests for gathering the necessary data for analysis from the physical well model needed to be programmed. These tests are steady state and cycling state.

Steady-state tests The purpose of the steady-state tests, which are of a continuous pumping nature, are to give the researcher an idea of the drawdown required for various well screens and development techniques. These data are required because the lower the drawdown is, the more efficient the pumping process is. These tests require all pressure data, including piezometric surface, lapsed time (from first read) and flow through the pump.

Cycling state tests Cycling state tests are taken during various well development techniques. These tests show the response of the aquifer to the well screen development techniques and the well screen's efficiency in allowing the pressure's rapid, periodic fluctuation through the screen to the aquifer. The piezometric surface and flow through the pump are not taken during cycling state tests as they are not required.

Utility programs Output programs for each type test and programs which allow quick loading of the data onto a file created on the Cyber system are required. The output programs unload the data in an understandable format onto a hard copy device for future reference.

Program and system particulars

The configuration of the minicomputer system was a major concern since improper hardware configuration leads to unpredictable and difficult to locate software failures. It was found that recommendations from the suppliers personnel, who assisted in the configuration design, were satisfactory and the final configuration enabled the system to produce dependable data acquisition operations with a high degree of system software speed.

Procedure files were created for each test run type and output type. Since a procedure file can be used by the MINC software to totally operate the programs and related hardware, a decision was made to utilize them. This decision allows users, who have little or no MINC system knowledge, to use the system immediately; however, it also requires the programming to be self-checking so errors which may occur can be flagged and corrected. Failing program correction, the error flags are used to notify the user of the type and probable causes of the error(s) in time for correction by the user.

Fortran was chosen as the best available high level language to operate the physical well model and perform the data acquisition algorithm. Fortran allows the use of additional macros needed over the systems software standard package. These macros can be easily appended to programs through the MINC's operating software.

Stepping through a typical run

A typical run of a test can be tracked using the general flow chart (figure 2).

Prior to actually operating the computer data acquisition system on the well model, the user must determine the run numbers and types of tests along with each test's various operation parameters required for obtaining the data the user needs. The MINC system is a "roll-away" system; therefore, the entire apparatus must be moved from its storage area into the test vicinity. Through use of the clips or plugs, input leads are attached to the A/D card, DI card and DO card. Next, the MINC is plugged in, floppy disks are loaded in the drives and the main power switch is turned on. The system will immediately boot up, and the power on parameters are requested by the procedure file. Once the power up parameters are set, the boot is completed, and the scanivalve is sent to the home position. User instructions such as types of tests available and how to call them are displayed on the console, and the system awaits the user's decision.

When the user has selected the type of test to be run, a run number is requested for identification purposes. Upon receipt of the run number, file management operations take place and space for the data file is reserved on the data disk. The basic parameters of how the user would like the test to be run by the program are requested, and, after user input, the basic parameters are checked by the program to determine if they are within an acceptable range. If they are not, an error message is displayed on the console and new parameters are requested. After the basic parameters are recognized as acceptable, the timing parameter is checked. If the timing parameter is below five-tenths (0.5) second, the program assumes minimum timing possible is desired and resets all timing parameters to the minimum plus safety factors.

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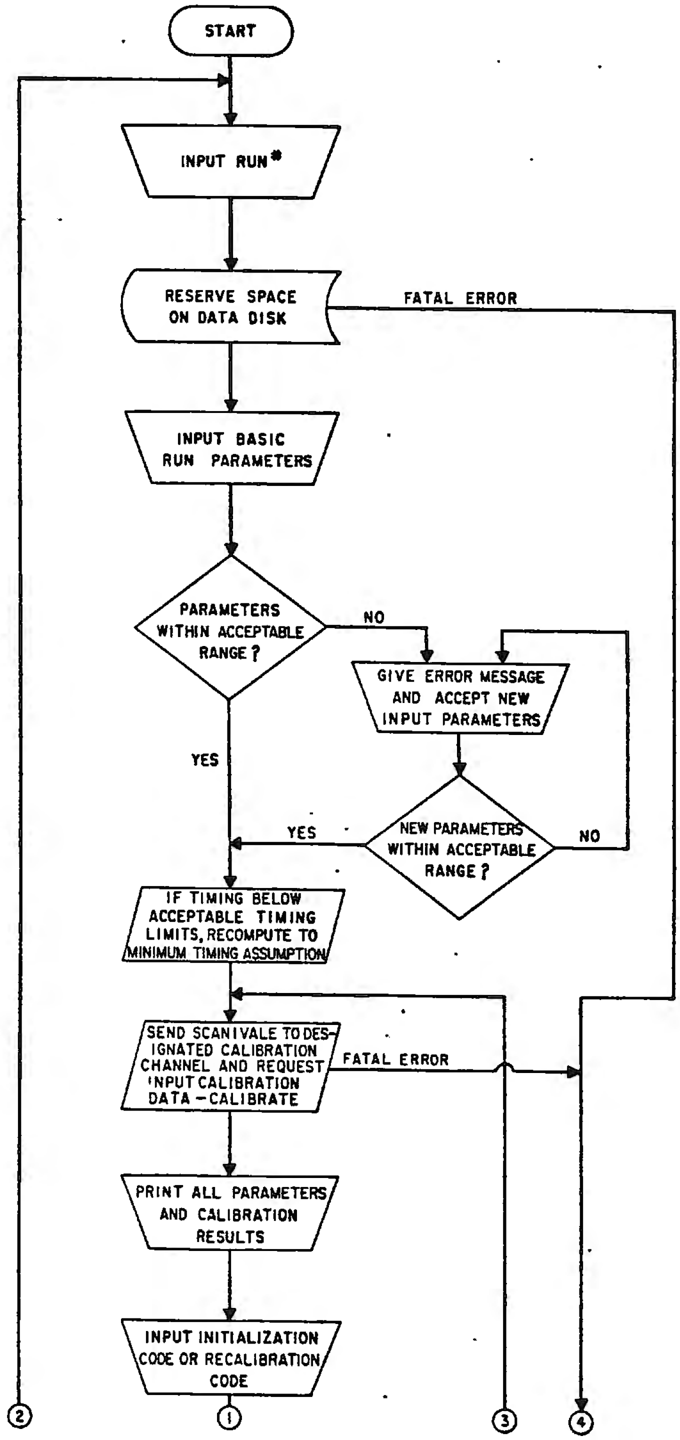

Figure 2. - Test programming flow chart.

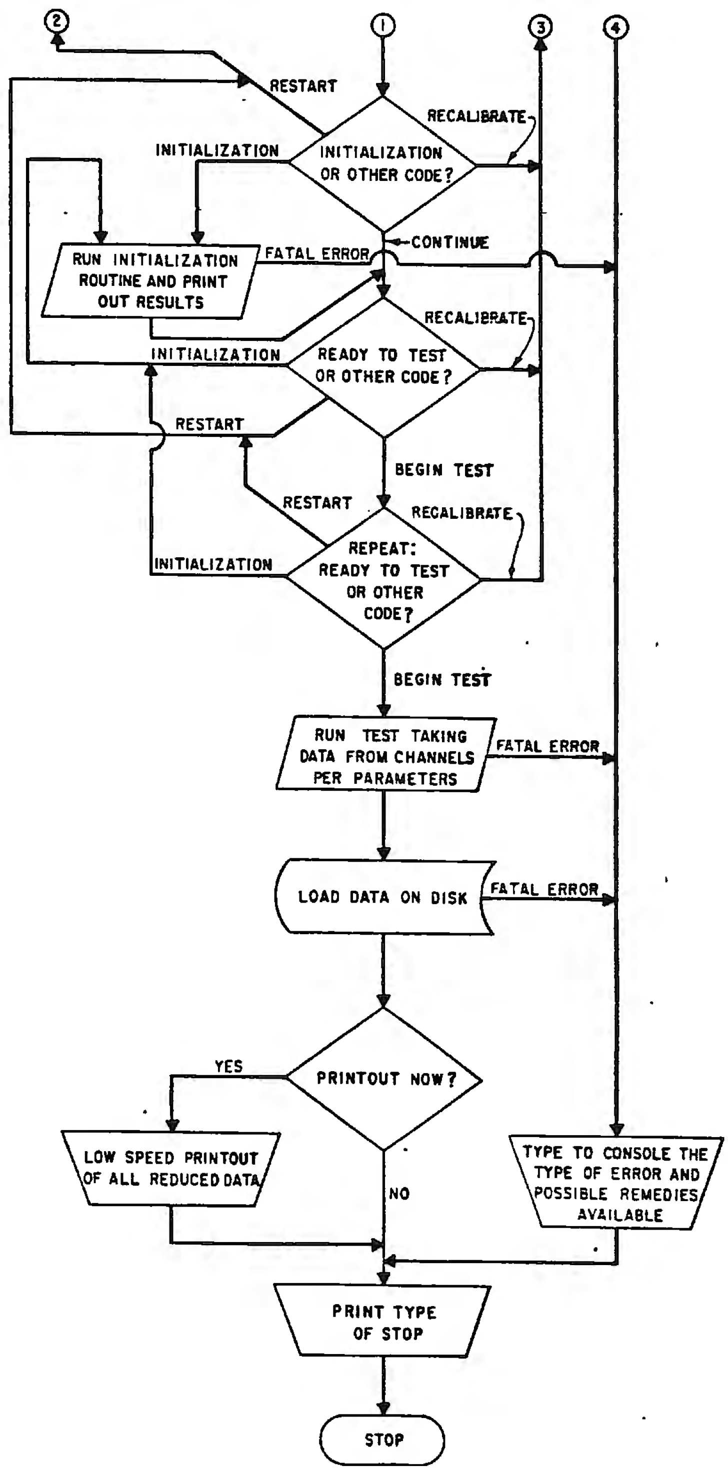

Figure 2. - Test programming flow chart.
(continued)

At this point calibration of the transducer is required; therefore, the program sends the scanivalve to the calibration channel and calibration instructions are relayed to the user. Upon receiving the required responses from the user, the calibration takes place, and the results, along with all input parameters for the test, are displayed on both console and terminal hard copy. If the user finds this information acceptable, the user's initialization parameters are set and, if desired, initialization variables are displayed on the console and terminal hard copy. If displayed, and initialization variables are acceptable, the user gives a go code and the test begins. If the initialization variables are not acceptable, the user gives an appropriate program execution code, and the program will return to the program location indicated by the user supplied code.

Once data acquisition has been initiated, the user is purposely committed to the data acquisition sequence and the data disk is loaded with the test data. (Only a total program abort will be accepted by the system.)

When the test data have completed loading onto the data disk, the user has the option of selecting immediate hard copy on the local terminal device. (Usually this option is not selected because the local terminal device's maximum speed is only 300 Baud.) The program then ends with appropriate messages about the program's operation.

If desired, the user is now free to select a new type of test and begin a new sequence. At any time the system is not taking data, if a high speed printer is attached and the output program for the type of test data involved is called, the output program will allow the user to output data previously stored on the data disk in an understandable format to the high speed printer. (The user may also select the low speed printer if the high speed printer is unavailable.)

Attaching the MINC serial port to the Cyber hardline or telephone modem and calling the terminal program allows the user to dump the designated data file into a Cyber file for further analysis.

Additional notations to typical run Since minimum timing of data input is desired, having the program wait until just prior to the need to change the scanivalve position for taking data ensures that data signals are relatively free from interference. The program then immediately changes the scanivalve position and reduces the data during the specified lag time. The MINC system is then prepared for the next scan sequence. Once the specified time span has passed and the above operations have been performed, the sequence is repeated until all piezometers have been read. In the well model, this particular flow scheme is critical to ensure that all data received are acceptable.

BENEFITS OF THIS SYSTEM

This computer system enables the physical well model researcher to obtain data that were previously unavailable, due to the nature of the porous media problem. Timing, accuracy, and the ease of operation of the minicomputer system ensure the researcher that the data are correct and capable of being analyzed.

USING THE SYSTEM ON FUTURE PROJECTS

To be cost effective, the expenses associated with a minicomputer system mandates that the system be used by several research projects. Through the development of subroutines for other programmers' reference and the programming of general purpose procedures, potential users of the system can become familiar with and gain confidence in the new minicomputer system. This familiarity and confidence are of primary importance to acceptance of any computer system. Thus, when the need for special purpose programming arises, such as that required for the physical well model, the researcher is able to make educated decisions regarding the choices available when using a minicomputer assisted data acquisition system.

References

Carlson, E. J. Physical well model data logs for the period 1975 to 1981. Unpublished data logs, Bureau of Reclamation.